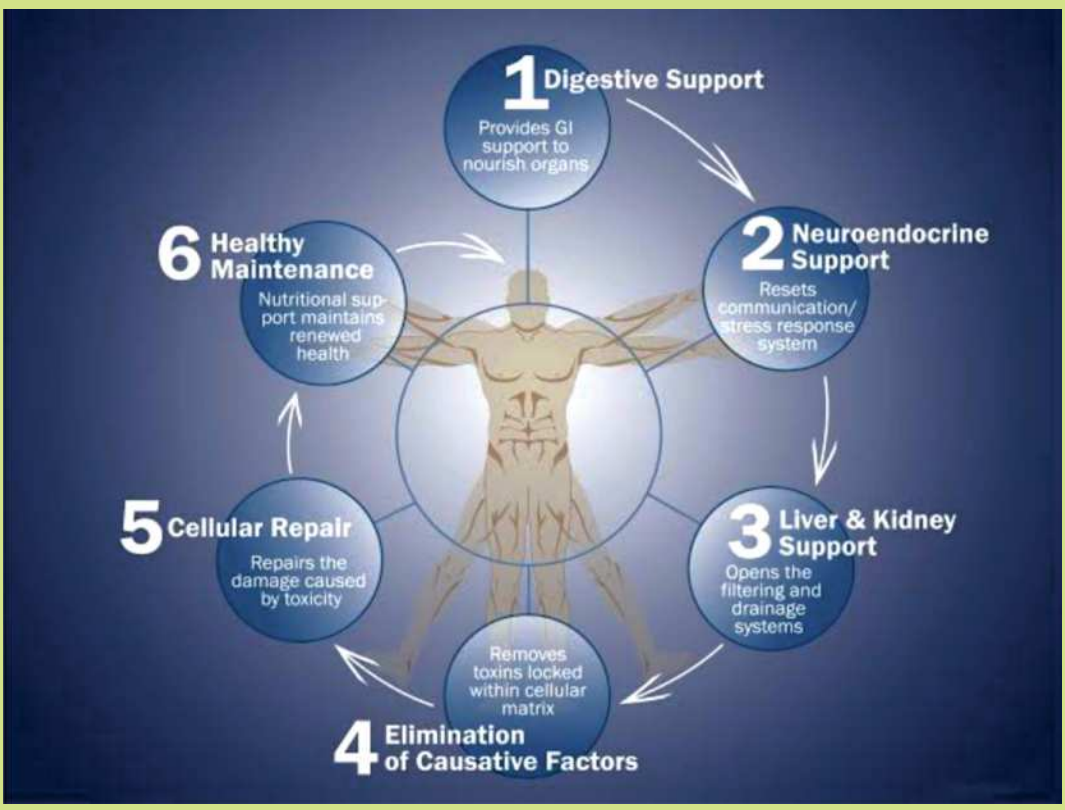
BIOENERGETICS

Chapter 7

Major Concept

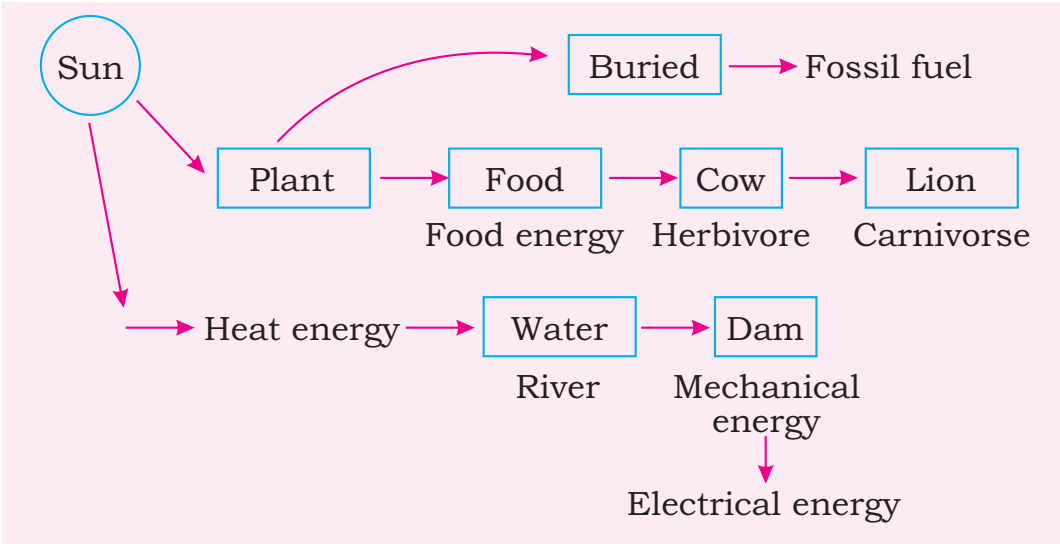
In this Unit you will learn:

- **Introduction and Role of ATP**
- **Photosynthesis**
  - Introduction of Equation
  - Role of Chlorophyll and Light
  - Limiting Factors in Photosynthesis
- **Respiration**
  - Aerobic Respiration, Anaerobic Respiration
  - Mechanism of Respiration (Glycolysis, Krebs Cycle, Electron Transport Chain)



Every machine requires energy (Capacity to do work) for performing its functions, like automobiles which require fuel to produce energy. Cell phones have batteries which store energy and utilize it for their working. Living Organisms are also like machine which require nutrients in the form of food. The special molecules of food contain energy. Here question arises, from where this energy comes in fuel and food molecules?

The only source of energy on earth is Sun. Energy of the Sun reaches earth in the form of light (light energy). This light energy is converted into chemical energy by living organisms or in heat energy stored by non-living things.



The above chart shows that conversion of energy from one form to another form explained by law of conservation of energy or first law of thermodynamics which states that energy can neither be created nor be destroyed but it can change from one form to another form.

As we can see that the heat energy of light converts in K.E. energy which flows water. This K.E. of water in dams is converted into mechanical energy when falls on turbine. This mechanical energy converts into light energy in bulbs and LED lights or again in mechanical energy in our fans.

On the other hands this light energy when falls on green parts of plant is captured and converted into chemical energy. This chemical energy is stored as food energy in plants. When these parts of plant are eaten by

animal this energy transferred into them, where the organisms buried and remain under pressure inside earth crust for millions of year their chemical energy is converted into fossil fuel.

7.1 BIOENERGETIC AND ROLE OF ATP

The study of this conversion of free energy into different forms by living organisms is called **Bioenergetics**. It is the part of biology, Physics and chemistry concerned with the energy involved in making and breaking of chemical bonds found in the molecules of organisms. Bioenergetics can also be defined as the study of energy relationships, energy transformation and transmission in living organisms.

7.1.1 Chemical Process of Energy Transmission:

In living organisms the energy is transferred through gain or loss of electrons during formation and breaking of chemical bonds. There are two chemical processes where it occurs, known with the name of oxidation and reduction. The oxidation reactions are those reactions in which loss of electron (e-) and proton occurs. These electrons carry energy from the molecules from where they release to the molecules where they added e.g. iron reacts with oxygen to form a chemical called rust, in this reaction iron (Fe) loses some e- which transfer to oxygen. In this reaction Fe is oxidized and it transfers its energy to oxygen through electrons. On the other hand, reaction occur called reduction, where gain of e- and H+ occur. This gain of e- also brings energy which is stored in it.

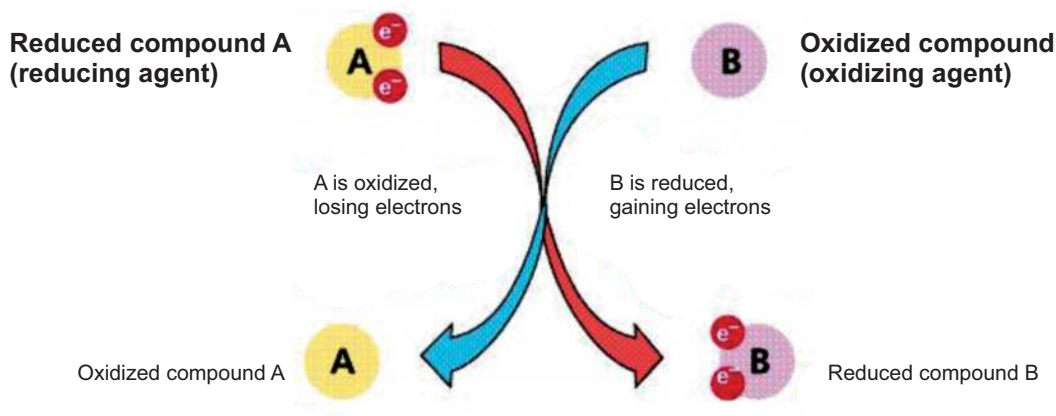
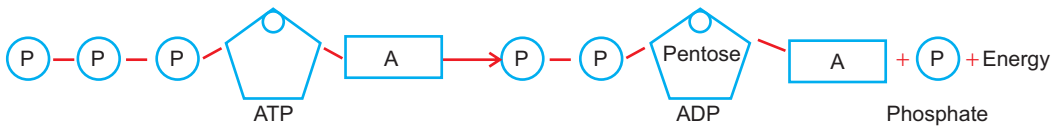


Fig:7.1 Diagram showing oxidation and reduction process

In living organisms these oxidation - reduction (Redox) reactions occur continuously to transfer energy from one molecule to other molecule, without these reactions energy transfer becomes impossible in living system.

7.1.2 Energy Currency in living organism:

In our home we store energy in batteries when electricity is available from usual source or when light energy is available we capture it by solar plates. This energy of battery then is utilized at the time of power shutdown (load shedding). Living organisms also have similar type of system to store energy. This energy is stored in a special molecule called Adenosine Tri-Phosphate (ATP). In organisms, energy is liberated during any oxidation reaction, this energy is utilized by molecules called Adenosine Di-Phosphate (ADP) to form a bond with phosphate (P). As a result the ADP become ATP, energy of oxidation is now stored in ATP.



The amount of energy stored is 7.3 Kcal / mole, this stored energy in ATP will be utilized by living organism for performing any type of work e.g. transport of molecules against the concentration gradient. The energy is now become free (liberated) by breaking ATP molecule.

$$ATP \longrightarrow ADP + P + Energy\ (7.3\ K\ Cal\ /\ mole)$$

So the formation of ATP is endergonic (energy intake) process and breakdown of ATP is exergonic (energy liberating) process.

7.2 PHOTOSYNTHESIS

Photosynthesis is the fundamental process in which basic organic molecules and O_2 are produced for all bio-molecules and living organisms. This process in carried out by chlorophyll containing organisms like plants, algae, some protozons and some bacteria. Word **photo** means **light** and **synthesis** means **to prepare**. Plants utilize simple inorganic molecules carbon dioxide (CO_2) and water (H_2O) which react by using light energy in the presence of pigments like Chlorophyll to form glucose and oxygen.

Equation:

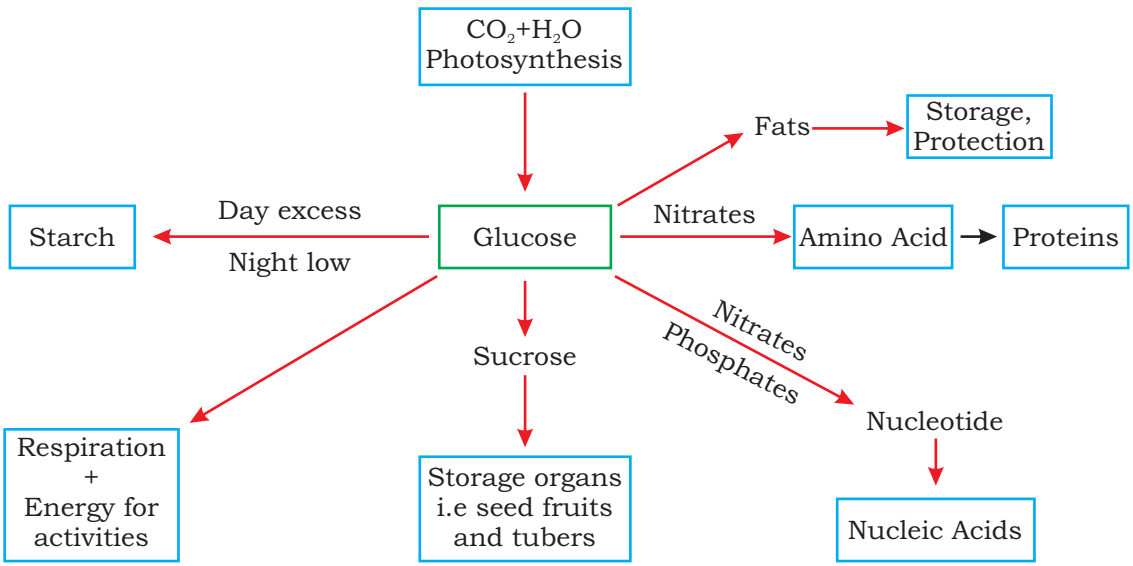
$$\text{Carbondioxide + Water} \xrightarrow[\text{Chlorophyll}]{\text{Light}} \text{Glucose + Oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow[\text{Chlorophyll}]{\text{Light}} C_6H_{12}O_6 + 6O_2$$

Chlorophyll is the green pigments found in the chloroplast of plant cell. It captures a specific part of visible light only, therefore it is not a reactant but absorbs energy needed to drive the reaction. In other words photosynthesis converts light energy into chemical energy.

The fundamental molecule produced during photosynthesis is simple sugar i.e. Glucose. Glucose utilizes in most of the metabolism of plant to produce secondary products like starch and other polysaccharides. Plants also use carbohydrates to form fats, proteins and other chemical like Nucleic Acids.

This glucose is also used in respiration as reactant to produce energy for the metabolism of living organisms.



Different forms of life completely depends on Photosynthesis

Plants are not the only organisms which depend on photosynthesis but animals (Heterotrophs) also depend on phototrophs. These organisms utilize the molecules of phototrophs as food molecules. If an animal is herbivorous it feeds directly on plants. If an animal is carnivorous it depends on those animals which feed on plants. These feeding sequences and relationship are called Food Chains.

On the other hand photosynthesis is the only process which produces free O_2 by splitting water. This O_2 is utilized by all living organisms for respiration to produced energy for metabolism. Without O_2 living organisms cannot survive. Through Photosynthesis quantity of CO_2 and O_2 in nature is maintained by plants. During Photosynthesis plants fix CO_2 and release O_2 in environment.

CO_2 has a property to absorb heat of sun. If its quantity increases in environment, there will be increase in an environmental temperature on earth called Global warming. Photosynthesis keeps the quantity of CO_2 maintained in environment i.e. indirectly keeping the concentration of CO_2 to maintain the temperature of earth.

7.2.1 Chloroplast as light Trapping and storage organelle:

Green part of plants and algae contain special cell which contain special organelle called chloroplast. Chloroplast is a double membrane bounded organelle, have semi-fluid proteins containing medium called **Stroma**. Another network of membrane is also embedded in it called Thylakoid membrane, somewhere this thylakoid are piled at one another in stack called Grana (Singular - Granum).

The simple looking reaction of photosynthesis is not as simple as it looks. It involves number of chemical reactions which are catalyzed by number of enzymes, either in non cyclic or cyclic ways. Each reaction occurs at different site in chloroplast i.e.

1. Reaction in which light energy converted into chemical energy and stored in ATP (Adenosine Triphosphate) and $NADPH_2$ (reduced Nicotine amide Adenosine Dinucleotide Phosphate). This conversion occurs at thylakoid membrane where solar energy is captured by pigments located in harvesting complex. This phase of photosynthesis is called light Dependent reaction. It is non Cyclic process coupled with breakdown of H_2O molecules i.e. photolysis, takes place also at thylakoid membrane.

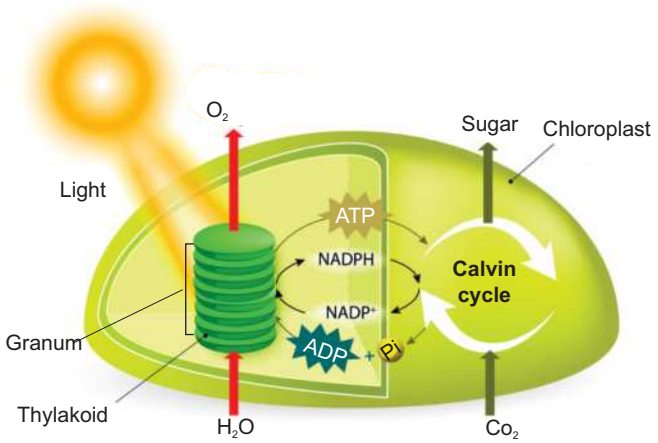


Fig: 7.2 Photosynthesis: light dependant and light independent phase in chloroplast

2. Reaction in which captured solar energy transferred to glucose from ATP and $NADPH_2$. It takes place in stroma, in cyclic manner. During this phase fixation of atmospheric CO_2 also takes place to form organic molecules.

7.2.2 Two phases of Photosynthesis:

Processes of Photosynthesis is mainly divided into phases or reactions.

1. Light Reaction or Light Dependent reaction.
2. Dark Reaction or Light Independent reaction

1. Light Reaction or Light Dependent Reaction

The term light reaction or light dependent reaction is used due to the reason that during this phase of photosynthesis light energy is captured and converted into chemical energy.

Some of the light is utilized to split water into oxygen and H^+ with e^- (electrons), this splitting of water is called Photolysis. Oxygen which is produced during photolysis is released in the environment where as H^+ together with CO_2 are used in building Glucose.

In chloroplast, different pigments absorb light of different wave lengths. Among them chlorophyll is the main light capturing molecules in thylakoid membrane which absorbs violet, blue and red light but reflects green therefore it appears green. In the thylakoid membrane other pigments and electron carrier molecules form highly organized assemblies in a series called photosystems. Each thylakoid contains

thousands of copies of two different kind of photosystems called photosystems I and II. Each consists of two major parts, a light harvesting complex and an electron transport system.

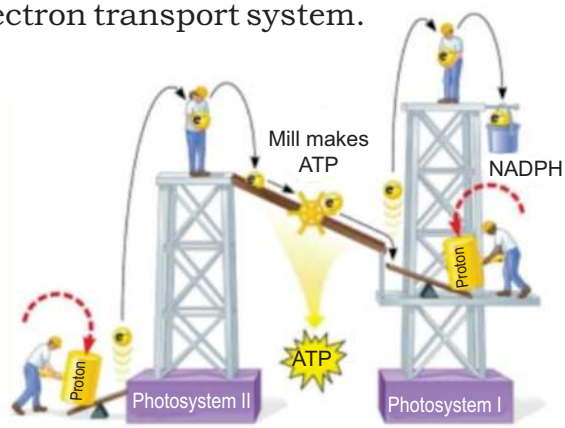


Fig: 7.3 scheme of light reaction

The conversion of light energy takes places when the chlorophyll of reaction center receives energy. One of the electrons from chlorophyll "a" molecule leaves and jump over the electron transport system. This energized electron moves from one e^- carrier to next. The electron releases energy, when it comes down, this energy drives reactions and produces two energy rich compounds. These are:

i) ATP (Adenosine Triphosphate)

ii) $NADPH_2$ (Reduced Nicotinamide Adenosine Dinucleotide Phosphate)

ADP is the compound which is already present in cell. It combines with phosphate by using energy of photon released from when moving through e^- carriers in photosynthesis.

$$ADP + P \xrightarrow[\text{Enzyme Complex}]{\text{Light energy}} ATP$$

NADP also present in chloroplast is reduced into $NADPH_2$ by accepting Hydrogen ions (H^+), released from splitting of water.

$$NADP + \underbrace{2\,H^+ + 2e}_{\text{From Water}} \longrightarrow \underset{\text{Reduced form}}{NADPH_2}$$

Cell

ATP and $NADPH_2$ both are energy rich compounds which provide energy, Hydrogen (H^+) and e^- for the conversion of atmospheric CO_2 into carbohydrates in chloroplast during light independent Phase of photosynthesis.

2. Dark Reaction or Light Independent Reaction:

This phase of photosynthesis does not require energy of photon but also takes place in day simultaneously with the light reaction. The ATP and $NADPH_2$ synthesized during the light dependent reaction are dissolved in stroma there, they provide energy to power the synthesis of Glucose from CO_2 and H_2O (i.e. H^+ and e^- of water). This Phase occurs independently, without light as long as ATP and $NADPH_2$ are available.

This phase of photosynthesis is cyclic phase. It occurs in set of reactions also called Calvin – Benson Cycle due to it's discover or the C_3 (three Carbon Containing Compounds formed initially) Cycle.

The C_3 Cycle requires

1) CO_2 - normally from air some of it also comes from respiration.

2) CO_2 Capturing Sugar - a Pentose Sugar.

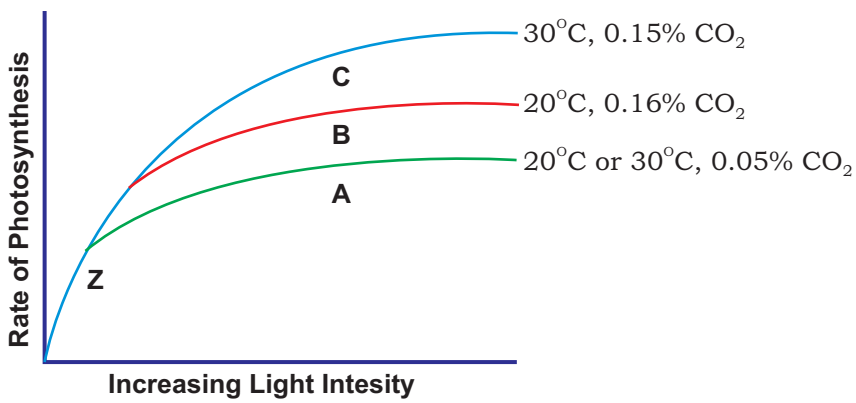
3) Enzymes to catalyze all the reactions.

4) Energy from ATP and $NADPH_2$ come from light dependent reaction.

7.2.3 Limiting Factor

Rate of biochemical reaction dependent on some factors which affect the rate are called limiting factor. For example at low light intensity rate of photosynthesis increase continuously but at high light intensity the rate becomes constant.

Light intensity, Carbon dioxide concentration and temperature can all be limiting factors for the rate of photosynthesis. Following graph shows the idea of limiting factor.



A- At point Z on graph, light intensity is limiting factor.

B- If light intensity increase to bright light and moderate temperature the concentration of CO_2, in air becomes limiting factor. It is clearly observed that the same plant if put into air containing high CO_2 then the rate of photosynthesis becomes high.

If there is high light intensity and high CO_2 concentration then the temperature becomes the limiting factor but the temperature should not be very high otherwise enzymes become denatured.

Activity: Find out the effect of light intensity on the rate of photosynthesis

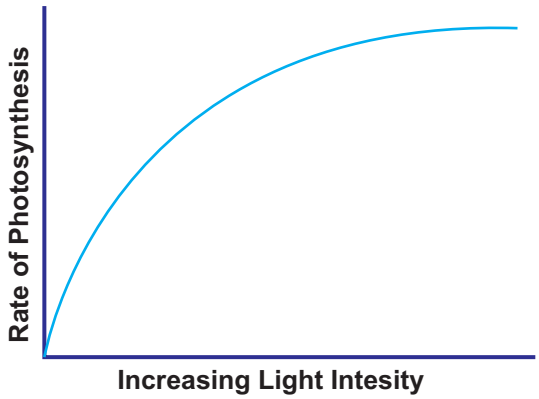
Apparatus:

Large beaker of water, boiling tube, stand and clamp, paper clip, fresh water plant hydrilla, ruler, stopwatch, thermometer, lamp etc.

Procedure:

1. Take a healthy piece of Hydrilla. Place it upside down in a boiling tube of water. It helps to sink the Hydrilla.
2. Clamp the tube to hold it upright in beaker of water. Ensure that the plant is perpendicular to source of light. The beaker of water is needed to maintain a constant temperature.
3. Place a thermometer in water to record the temperature. Turn off the room lights to reduce back ground light and place a bench lamp close to the beaker.
4. Observe the plant for few minutes, you will see the bubbles of gas coming out from the cut end of plant. If no bubbles are seen repeat the experiment by using fresh piece of plant. Count the number of bubbles per minute. If the rate of bubbling is too fast to count, move the lamp away from the breaker until the rate becomes countable.
5. Repeat the counts until you are sure that the rate is constant. Record the rate and the distance of the lamp from the plant.
6. Change the distance of lamp from plant and take more measurement of the rate of bubbling at each distance. Take 3 values at each point.
7. Repeat the counts at different distance from plant keep the temperature of water constant thought out the experiment.

Suppose that the rate of bubble production is the measure of the rate of photosynthesis. It is concluded that the rate of photosynthesis decreases at low light intensities. As the lamp is moved away from plant, the intensity of light falling on it also decreases.



7.3 RESPIRATION

To carry out all the life process cells requires energy. The source of this energy is food or photo assimilates (Products of photosynthesis) in plants. Cells break food molecules to release their Chemical energy. The breakdown of food molecules to release energy is called **respiration**.

Usually cells use oxygen to oxide food. It results CO_2 and water as waste products. The main food oxidized is the sugar i.e. Glucose. The overall equation for this chemical reaction is:

Glucose + Oxygen $\longrightarrow$ Carbon dioxide + water + Energy

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + ATP$$

Above equation shows that one molecule of glucose reacts with six molecules of oxygen to produce six molecules of carbon dioxide and six molecules of water. The main product is energy which is produced in the form of energy rich molecules called ATP.

It is commonly believed that breathing and respiration processes are same but factually they are different, although they are linked. As we have discussed above respiration is the chemical reaction takes place in cells to release energy from food while the breathing is the movement of air in and out of the organism to supply O_2 and CO_2. We use another term for breathing called Ventilation. Breathing allows the process of gaseous exchange at surface of cells and tissues. So the terms breathing, gaseous exchange and respiration are different from one another but linked together to make possible energy production at cellular level.

7.3.1 Type of Respiration

There are two types of respiration found in living organisms for the production of energy.

i) Anaerobic Respiration or Fermentation ii) Aerobic Respiration

(i) Anaerobic Respiration:

The primitive type of respiration which takes place in the absence of O_2 or without O_2 is called anaerobic respiration or fermentation. There are special conditions where O_2 is not available so the organisms adapt themselves to break down their food without oxygen which is called anaerobic respiration or fermentation. It takes place in some bacteria, fungi, endoparasite and sometimes in animal.

During anaerobic respiration, glucose is not broken down completely so less amount of energy (5 to 10% as compared to aerobic respiration) is released but it can sustain life even in the absence of O_2. It had evolved on earth where there was no O_2 on earth. There are two types of anaerobic respiration.

Alcoholic fermentation:

The bacteria and fungi respire aerobically but when these organisms are deprived of oxygen they stop respiration aerobically and start respiring anaerobically instead, During this anaerobic respiration they produce ethyl alcohol with CO_2.

$$\text{Glucose} \longrightarrow \text{Ethanol} + CO_2 + \text{Some energy}$$

$$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2 + \text{Some ATP}$$

Acidic fermentation:

In animals when aerobic respiration is not enough to produced required energy they start anaerobic respiration. During this process glucose breaks down into a substance called **lactic acid**.

$$\text{Glucose} \longrightarrow \text{Lactic acid} + \text{Some energy}$$

$$C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3$$

A limited amount of energy is produced as compared to aerobic respiration but this is enough to power the athlete's muscles during start time of sprint. He experiences pain, this condition of pain is called Muscle fatigue. The lactic acid is produced in his muscles and bool stream.

Importance of anaerobic respiration:

As we have discussed earlier that anaerobic respiration is the emergency arrangement of energy which has an advantage that organisms can survive without O2 or can work for short period with same pace for short period. The other products of anaerobic respiration are acids. Vinegars are also organic acids that are produced commercially by acidic formulations.

Anaerobic respiration also produces ethyl alcohol. This process is commercially utilized by making alcoholic products like beer, wines and other beverages.

Baking industry is also based on it because anaerobic respiration also produces CO_2 which gives fluffy and soft shapes to cakes and breads also break down of starch into complex sugar to form bread and pizza.

(ii) Aerobic Respiration:

Type of respiration where food breakdown occurs in the presence of oxygen to produce energy. It is a method of respiration found in majority of organisms. It takes place in the presence of free oxygen, oxidizing the food and releasing the maximum amount of energy i.e. 2827 kj / mole of glucose or 36 ATP molecules/glucose.

The end products of aerobic respiration are CO_2 and H_2O

Glucose + oxygen $\longrightarrow$ Carbon dioxide + water + Energy (36 ATP)

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 36\ ATP$$

7.3.2 Mechanism of aerobic respiration:

Aerobic Respiration takes place in 3 steps at different places in the cell.

(a) Glycolysis (Gr. Glyco = Sugar, Lysis = Break down):

First stage is that stage where a molecule of glucose (Six carbon sugar) is broken down into two molecules of pyruvic acid (three carbon acid). It does not require oxygen. It takes place in both aerobic and anaerobic respiration. This splitting of glucose releases small amount of energy of glucose which is enough to generate 2 molecules of ATP. Glycolysis is a complex sequence of reaction all occur in cytosol.

(b) Kreb's or Citric acid Cycle:

The second stage of aerobic respiration in which pyruvic acid produced during glycolysis enters the mitochondria where O_2 available. Cellular respiration uses this O_2 to break pyruvic acid completely into CO_2 and H_2O in a cyclic manner. During Kreb's Cycle some ATP produce and some co-enzymes like NAD and FAD are reduced to $NADH_2$ and $FADH_2$. It takes place in matrix of mitochondria.

(c) Electron Transport Chain:

The last stage of aerobic respiration in which $NADH_2$ (Nicotinamide Adenosine Di-nucleotide) and $FADH_2$ (Flavinamide Adenosine Di-nucleotide) are oxidized to produce ATP and H_2O. It takes place at the cristae of mitochondria.

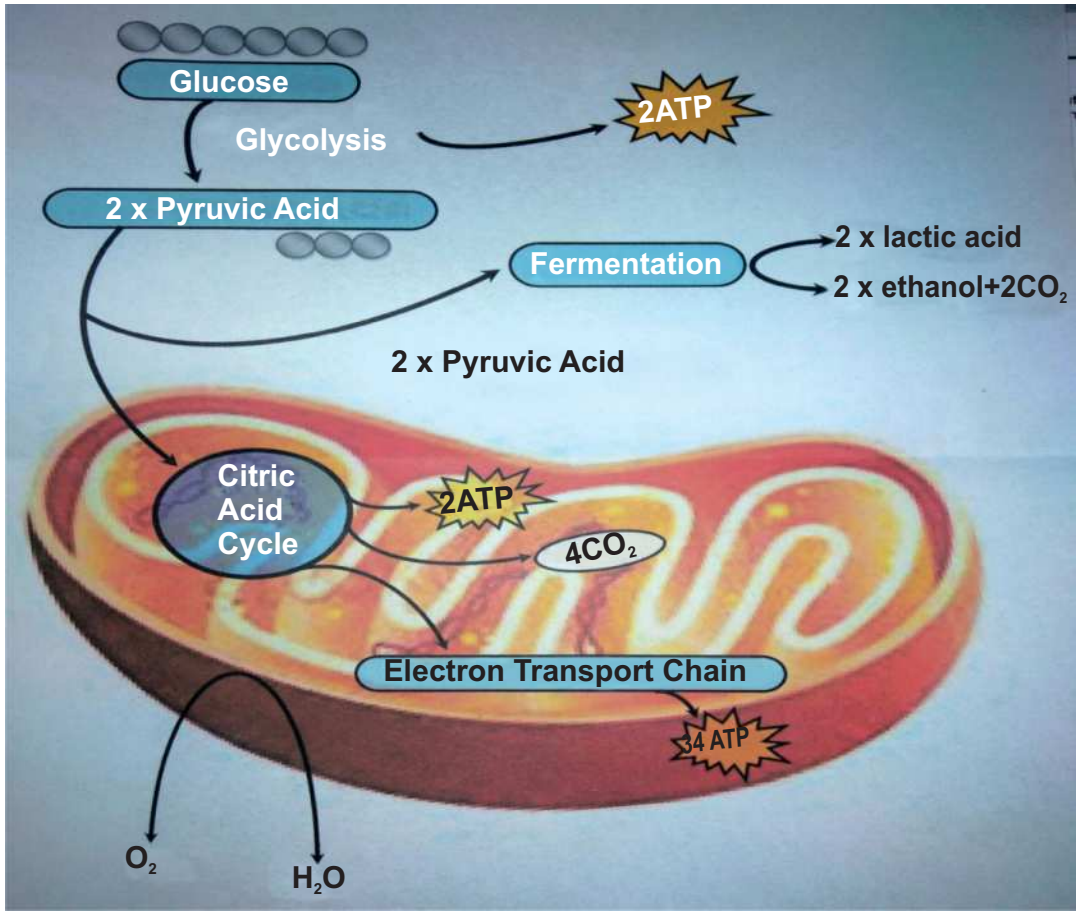


Fig: 7.4 Aerobic respiration in Mitochondria

7.3.3 Usage of Respiration Energy in the body of Organisms:

Number of Processes requires energy in the body of an organism. Body provides it from respiratory energy. Following are some process which utilize respiratory energy.

- Synthesis of molecules — Formation of different molecules as well as large molecules from small molecules requires energy.
- Cell division — During cell division formation of large molecules like DNA and protein takes place which require energy as well as movement of chromosome also require energy.
- Growth without cell division — enlargement growth is not possible and both require formation of molecules which require energy.
- Active transport — movement of ions and molecules from low concentration to high concentration requires energy.
- Muscle Contraction — Movement of muscle requires energy which is produced from chemical energy, chemical energy converted into kinetic energy.
- Passage of Nerve impulse — Nerve Impulse (message of Neuron) is basically electrical signals moving long nerve fiber by active transport requires energy.
- Maintenance of Body temperature — In higher animal's body temperature is maintained at constant level, this temperature maintenance requires energy of respiration.

Photosynthesis	Respiration
• Photosynthesis is the process where light energy converted in chemical energy. • It occurs only in chlorophyll containing organisms. • It requires light sources i.e occur only in the presence of light. • It occurs in chloroplast. • The reactants are Carbon dioxide and water. • Products are glucose and	• Respiration is the process where chemical energy converted into energy of ATP. • It occurs in all organisms. • It does not requires light source so occurs throughout the life. • It occurs in mitochondria. • Reactants are carbohydrates and oxygen usually. • Products are carbon dioxide and water in the case of aerobic

Summary

- The study about conversion of free energy into different forms by living organisms is called bioengergetic.
- Energy conversion takes place during oxidation reduction reaction.
- ATP is the source of energy for metabolic reaction in living organism. This energy comes from carbohydrate or oxidation process or from other molecules.
- Photosynthesis is the fundamental process in which basic organic molecule and oxygen (O_2) are produced.
- Chlorophyll is the green pigment found in chloroplast of plant cell. It captures specific part of visible light.
- The fundamental produce during photosynthesis is simple sugar i.e Glucose.
- Plant and other heterotrophes are also dependant on phototrophes.
- Photosynthesis is the only process which produce free O_2 by splitting H_2O.
- Photosynthesis is consists of two Steps:

  (i) Light dependent (ii) Light independent reaction
- Reaction in which light energy converted into chemical energy and stored in the form of ATP and $NADPH_2$. This step called light reaction.
- Light reaction occur at thylakoid membrane.
- Reaction where captured light energy converted into glucose from ATP and $NADPH_2$, takes place in stroma of Chloroplast.
- The formation of ATP from ADP by using light energy called phosphorylation.
- Rate of biochemical reaction dependent on some factors which effect the rate called limiting factor.
- Some limiting factors of photosynthesis are light intensity Co_2, concentration and temperature.

- Break down of food molecules to release energy in cell is called respiration.
- The energy of food molecules specially glucose produce as oxidation energy.
- The oxidation energy is stored in ATP.
- There are two types of respiration:

  (i) Anaerobic respiration (ii) Aerobic respiration
- Respiration which takes place in the absence of O_2 called Anaerobic respiration or fermentation.
- Alcoholic and acidic fermentation are the types of anaerobic respiration.
- Type of respiration takes place in the presence of O_2 called aerobic respiration.
- Aerobic respiration occur in three steps:

  (a) Glycolysis, (b) Kreb's Cycle and (c) e^- Transport chain.
- Glycolysis where glucose convert into pyruvic acid is cytosol.
- Kreb's cycle where breakdown of pyruvic acid takes place aerobically to produce CO_2 and energy stored in $NADH_2$ and $FADH_2$.
- e^- transport chain where oxidation of $NADH_2$ and $FADH_2$ occur the oxidation energy produce and stored in ATP. It occurs at Cristae of Mitochondria.

Review Questions

1. Encircle the correct answer:

(i) In an oxidation process 14135KJ energy is release, how many moles of glucose consume during this process.

(a) 1 (b) 3 (c) 5 (d) 10

(ii) Stage of aerobic respiration takes place at the cristae of mitochondria called.

(a) Electron transport chain (b) Glycolysis

(c) Kreb's cycle (d) C3 cycle

(iii) In a process of cellular respiration 180 ATP molecules are produced, how many moles of glucose consume during this process.

(a) 2 (b) 5 (c) 8 (d) 10

(iv) Loss of electron and proton is called

(I) Oxidation reaction (II) Reduction reaction

(III) Redox reaction

(a) I only (b) I and II (c) II and III (d) I, II and III

(v) Each mole of ATP store energy

(a) 7.3 kcal/mole (b) 7.3kj/mole

(c) 17.3kcal/mole (d) 17.3kj/mole

(vi) Fundamental molecule produced during photosynthesis is

(a) Glucose (b) Amino acid (c) Fatty acid (d) Nucleotide

(vii) Light dependent reaction takes place in

(a) Stroma (b) Thylakoid (c) Cristae (d) Cisternae

(viii) Reaction in which solar energy is transferred to glucose from ATP and $NADPH_2$, takes place in stroma called

(I) Light reaction (II) Dark reaction

(III) Light dependent reaction

(a) I only (b) II only (c) I and II (d) II and III

(ix) Splitting of water in presence of light called

(a) Hydrolysis (b) Glycolysis

(c) Photolysis (d) None of these

(x) Splitting of glucose (glycolysis) release small amount of energy which is enough to generate

(a) 2ATP (b) 5 ATP (c) 18 ATP (d) 36ATP

2. Fill in the blanks:

(i) The only source of energy on earth is_____.

(ii) Conversion of free energy into different forms by living organisms is called_____.

(iii) In living organisms energy is stored in a special molecule called_____.

(iv) Plant utilizes simple inorganic molecules (CO_2 and H_2O) to prepare _____.

(v) Feeding sequences and relationships are called _____.

(vi) Photosynthesis is the only process which produces free O_2 by splitting_____.

(vii) Chloroplast is double membrane bounded organelle have semifluid protein containing membrane called_____.

(viii) In chloroplast different pigments absorb light of different _____.

(ix) The breakdown of food molecules to release energy is called _____.

(x) Each mole of glucose produce maximum energy i.e. _____.

3. Define the following terms:

(i) Bioenergetics (ii) Energy (iii) Oxidation reaction

(iv) Food chain (v) Granum (vi) Photolysis

(vii) Fermentation (viii) Stroma (ix) Aerobic respiration

(x) Pyruvic acid

4. Distinguish between the following in tabulated form:

(i) Respiration and photosynthesis

(ii) Light reaction and Dark reaction

(iii) Aerobic respiration and anaerobic respiration

5. Write short answers of following questions:

(i) How CO_2 maintain the temperature of earth?

(ii) Why second phase of photosynthesis is called dark reaction?

(iii) How respiration is different from breathing?

(iv) Why acidic fermentation is harmful?

(v) How glucose form secondary products in plants?

6. Write detailed answers of the following questions:

(i) What is energy currency of cell? Describe chemical process of energy transmission.

(ii) Describe phases of photosynthesis with suitable diagram.

(iii) Describe aerobic respiration in living system.